Alveolar recruitment manoeuvre in laterally recumbent anaesthetized sheep

L Bellini[1], A Valentini[1], M Bernardini[2]

[1]Veterinary Teaching Hospital, University of Padua, Italy.
[2]Department of Animal Medicine, Production and Health, University of Padua, Italy.

Background

- Sheep under general anaesthesia epecially in lateral recumbency, develop hypoxaemia due to ventilation/perfusion inequality, atelectasis with an increase venous admixture (Qs/Qt) [1,2]
- Alveolar recruitment manoeuvre (ARM) is a ventilatory strategy that re-expands collapsed alveoli and keep them open subsequently using positive end-expiratory pressure (PEEP) [3]
- A stepwise ARM applies progressive increases in PEEP and inspiratory peak pressure (Ppeak) to reopen area of atelectasis and improve alveolar ventilation.
- This technique improved arterial oxygenation and decrease Qs/Qt in dogs and horses [3,4] although no studies evaluate a stepwise ARM in sheep.
- F-shunt is a surrogate indicator of Qs/Qt that assume a fixed value of arterial-to-mixed venous oxygen content ($C(a\text{-}v)O_2$), equal to 3.5 mL dL^{-1} and strongly correlates with venous admixture in sheep[1].

Aim

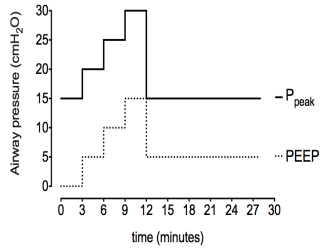
This study evaluates the efficacy of a stepwise ARM in improving oxygenation indices in left laterally recumbent, isoflurane anaesthetized sheep undergoing Magnetic Resonance Imaging.

Materials and methods

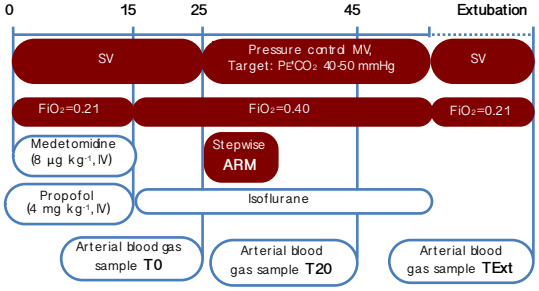
Animals

Six non-pregnant Brogna ewes (39 ± 5 kg)

Alveolar recruitment manoeuvre



Procedure



ARM, alveolar recruitment manoeuvre; **$Pe'CO_2$**, end expiratory partial pressure of carbon dioxide; **FiO_2**, fraction inspired of oxygen; **MV**, mechanical ventilation; **SV**, spontaneous ventilation. Time line expressed in minutes.

Formulas and measurements

$$CaO_2 = (Hb \times 1.31 \times SaO2) + 0.0031 \times PaO_2$$

$$Cc'O_2 = (Hb \times 1.31 \times Sc'O_2) + 0.0031 \times Pc'O_2$$

$$Pc'O_2 = PAO_2 = (FiO_2 \times [Pbar - PH_2O]) - PaCO_2 \times 1.2$$

$$F\text{-shunt} = ([Cc'O_2 - CaO_2]/[Cc'O_2 - CaO_2] + 3.5\ ml\ dl^{-1}) \times 100$$

0.0031, solubility coefficient of oxygen in ovine plasma; **1.31**, oxygen-carrying capacity of haemoglobin (mL g^{-1}); **CaO_2**, arterial oxygen content (ml dL^{-1}); **$Cc'O_2$**, Pulmonary end-capillary oxygen content (ml dL^{-1}); **FiO_2**, fraction inspired of oxygen; **Hb**, haemoglobin concentration (g dL^{-1}); **PAO_2(=$Pc'O_2$)**, Alveolar or pulmonary end-capillary partial pressure of oxygen (mmHg); **$PaCO_2$**, Arterial partial pressure of carbon dioxide (mmHg); **PaO_2**, Arterial partial pressure of oxygen (mmHg); **Pbar**, barometric pressure (mmHg); **PH_2O**, vapour pressure of water (mmHg); **SaO_2**, Arterial haemoglobin oxygen saturation (%); **$Sc'O_2$**, pulmonary end-capillary haemoglobin oxygen saturation (%).

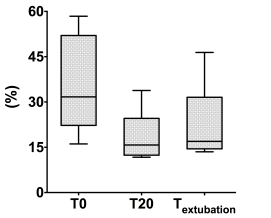
Because PAO_2 was > 100 mmHg in all sheep, $Sc'O_2$ was assumed to be 1.[2]

Results

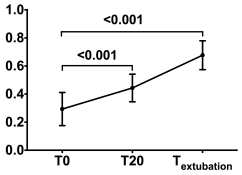
Variabiles		T0	T20	TExt
FiO_2		0.40	0.40	0.21
pH		7.357 ± 0.086a	7.385 ± 0.076a	7.402 ± 0.080b
PaO_2				
	mmHg	70 ± 28a	106 ± 25b	73 ± 13a
	kPa	10 ± 4a	14 ± 3b	10 ± 2a
$PaCO_2$				
	mmHg	55 ± 7	54 ± 6	50 ± 7
	kPa	7.4 ± 0.9	7.2 ± 0.8	6.7 ± 0.9
PAO_2				
	mmHg	239 ± 5a	241 ± 5a	108 ± 6b
	kPa	31.9 ± 0.8a	32.1 ± 0.6a	14.4 ± 0.7b
SaO_2	%	93 (70-98)a	99 (91-99)b	96 (80-97)ab

Data normally distributed are expressed as mean ± SD deviation otherwise as median (min-max). FiO_2, fraction inspired of oxygen; PAO_2, Alveolar partial pressure of oxygen; PaO_2, Arterial partial pressure of oxygen; $PaCO_2$, Arterial partial pressure of carbon dioxide; SaO_2, Haemoglobin oxygen saturation. Different letters in a row mean statistical significant difference (one-way ANOVA or Friedman non-parametric test $p<0.05$) between points.

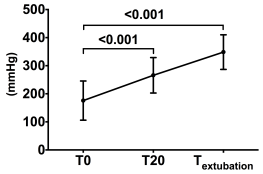
F-shunts



PaO_2/PAO_2



PaO_2/FiO_2



Median with interquartile range and min-max of F-shunt and mean ± SD of PaO_2/PAO_2 and PaO_2/FiO_2. One-way Anova or Friedman non-parametric test were used to analyse the data. Statistical signifcance was set at $p<0.05$.

Conclusion and clinical relevance

- General anaesthesia in laterally recumbent sheep under spontaneous ventilating may cause hypoxaemia as previously reported.[2]
- The stepwise ARM followed by mechanical ventilation with PEEP at 5 cmH_2O, improves the oxygenation indices and decrease the amount of venous admixture evaluated by the F-shunt.
- The positive effects of the ARM are still present in most of the animals at recovery.

References

1. Staffieri F, Driessen B, De Monte V et al. (2010) Am J Vet Res 71,867-874.
2. Araos JD, Larenza P, Boston RC et al. (2012) Am J Vet Res 73,2013–2020.
3. Canfrán S, Gómez de Segura IA, Cediel R et al. (2012) Vet J 194, 89-91.
4. Briganti A, Portela DA, Grasso S et al. (2015) Vet J 204, 351-356.

Ethical review

The study was approved by the Animal-welfare Body of the University of Padua (Authorization OPBA 7/2014) and the Italian Ministry of Health, according to European (Directive 2010/63/EU) and Italian regulations (Legislative Decree 26/2014)